General Electric Co. Incandescent Lamps.

Instruction Book

No. 8084

Guide to the Selection and Testing of Incandescent Lamps

From

GENERAL ELECTRIC COMPANY

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ILLUMINATION OF STAIRWAY IN THE CONGRESSIONAL LIBRARY.

GUIDE TO THE SELECTION AND TESTING OF INCANDESCENT LAMPS

INTRODUCTION.

The intelligent selection and proper use of incandescent lamps largely determine the volume and growth of electric lighting. Nothing produces such radical improve-

ILLUMINATION OF THE OMAHA EXPOSITION BUILDINGS.

The Grand Court, Looking East.

ment in the lighting service as, first, the exclusive use of the best lamp; and, second, the frequent and regular renewal of dim lamps. These principles are the precepts and practice of the leading central stations of the country, and should be law and gospel for every electric lighting company. This pamphlet has been prepared to illustrate the value of good lamps and to show how they may be distinguished from poor ones.

EXCLUSIVE USE OF THE BEST LAMP.

Central stations are in the business of making and selling light. They may sell by the ampere hour, the watt hour, the lamp hour, or by contract, but regardless of the way it is measured, the customer is in reality buying and using light. Since the lamp transforms the electrical energy of the generators into light, the best lamp is an absolute necessity to obtain the best light. It is, then, almost a self-evident truth that the exclusive use of the best lamp is the only means of obtaining the best results.

The *exclusive* use of the *best* lamp involves two conditions:—

First: The selection of the best lamp;

Second: The exclusion of all others.

To secure the exclusion of low grade lamps, central stations must control the supply of lamps used on the circuits. Complete control is practicable only by the adoption of a system of free renewals, the station supplying all the lamps used. Free renewals involve but a slight expenditure that will be more than returned by the increased meter income and the increased business resulting from the improved lighting service. At the present low price of lamps, free renewals can be profitably adopted by every station selling current by meter. When by reason of contract rates, it seems advisable to charge for lamps, the price should be sufficiently low (cost or less than cost) to enable stations to sell all the lamps used.

SELECTION OF THE BEST LAMP.

A high grade incandescent lamp has three distinguishing characteristics: first, the absence of all defects in the mechanical construction of the lamp; second, accuracy

and uniformity in candle-power and watt rating; third, good maintenance of candle-power in service and uniformity of performance in this respect. The best lamp may be selected by its excellence in these features.

Physical Defects.

Physical defects, such as loose caps or bases, poor or bad vacuum, spotted or discolored carbons, weak joints between filament and leading-in wires, etc., may be found in the average lamp to a greater extent than is generally known. These defects positively condemn a lamp, rendering it not only useless but troublesome. A casual inspection of lamps will reveal the prominent physical defects. Loose caps or bases are detected by twisting the cap and bulb; bad vacuums, in many instances, by causing the filament to vibrate—vibration will cease quickly in a poor vacuum. The filaments, when examined in the light, should reveal a clear, smooth, solid, dark-gray surface. At a dull red heat they should appear perfectly uniform and free from any bright or dark spots.

Correct and Uniform Rating.

Remarkably few makes of lamps are rated correctly and uniformly in candle-power. The National Electric Light Association made extensive tests on various makes of lamps in 1898 and drew the following conclusion:

> **"From this investigation. the fact stands out that the incandescent lamp sold for 16 candle-power is, on the whole, a lamp which is often giving considerably less than its rated candle-power, even when new."**

Lamps should measure well within 10% above or below rated wattage, and 10% above or below rated candle-power at marked voltage.

Target or "Shotgun" Diagrams.

The so-called Target or "Shotgun" Diagrams on the

ILLUMINATION OF THE OMAHA EXPOSITION BUILDINGS.

The Grand Court, Looking West.

following pages illustrate in a striking manner the variation in candle-power and watt ratings of several makes of lamps. The tests were made by a large commercial company and included fifty lamps of each make, purchased in the open market, without the knowledge of the manufacturers. These diagrams afford a unique and interesting means of illustrating the accuracy and uniformity of lamp rating. Vertical distances from the bottom of the diagram represent candle-powers, and horizontal distances from the left-hand side, the watts. The rectangle shown is the limiting target for well made lamps.

As the lamps tested were rated at 16 C.P., 3.5 watts per candle, the intersection of the horizontal 16 C.P. line and the vertical 56 watt line forms the center or "bull's eye" of the target.

The diagonal lines show the watts per candle-power.

The readings on each lamp in candle-power and watts at the marked voltage were noted and then plotted on the diagram by placing a dot at the intersection of the horizontal candle-power line and the vertical watt line corresponding to the readings. Poor marksmanship in lamp manufacture is thus clearly brought out.

As a caution to purchasers, however, it may be stated that this preliminary test, or initial rating, may not show the real value of a lamp. Any manufacturer may carefully select lamps so that they will be correct and uniform in rating. The test is of value, therefore, only with the *average* product, and not with specially selected lamps.

Correct and uniform rating will not ensure good candle-power maintenance any more than a correctly measured piece of cloth ensures good quality of material.

At the same time, this test serves to show at once the careless or incompetent manufacturer, when the average

product is considered. It also records a lamp's true rating, in order that comparisons may be correctly made, and any further tests properly conducted. Correct and uniform rating is desirable because it ensures:

1. Full and uniform brilliancy, and avoids the marked contrasts which a wide range in candle-power gives, and which are so detrimental to good lighting effects.

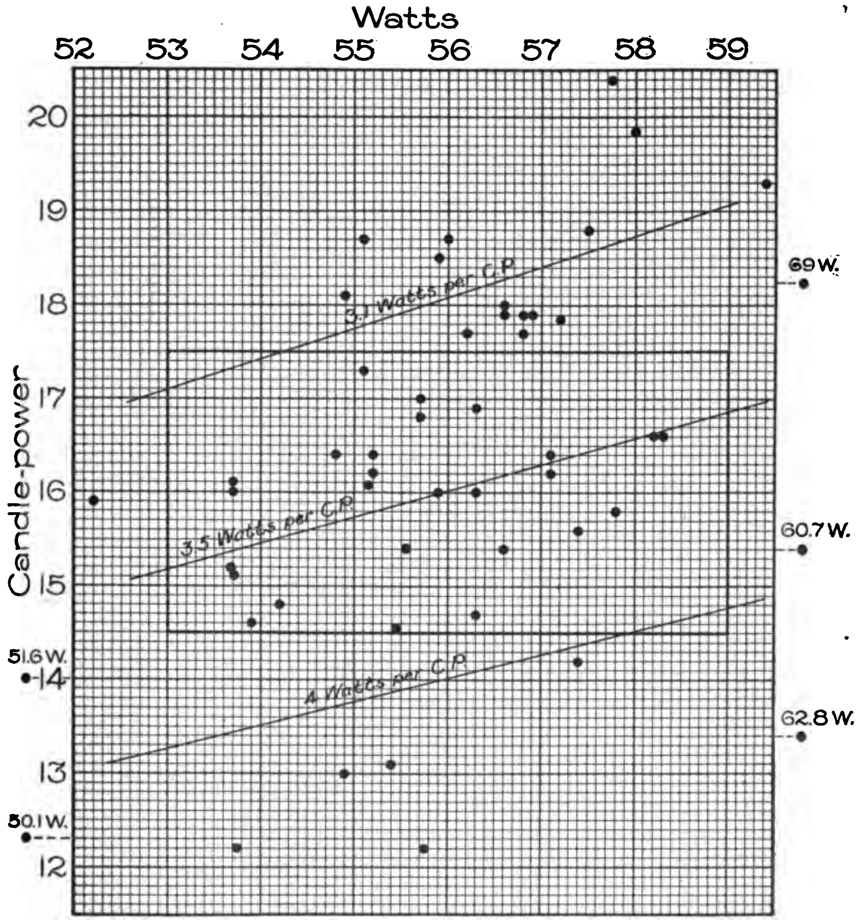
2. Uniform power consumption and definite meter bills, and, therefore, satisfaction to customers.

3. Good average life by reason of the uniform initial economy of the lamps.

These points are brought out in the descriptions accompanying each diagram.

TARGET DIAGRAM

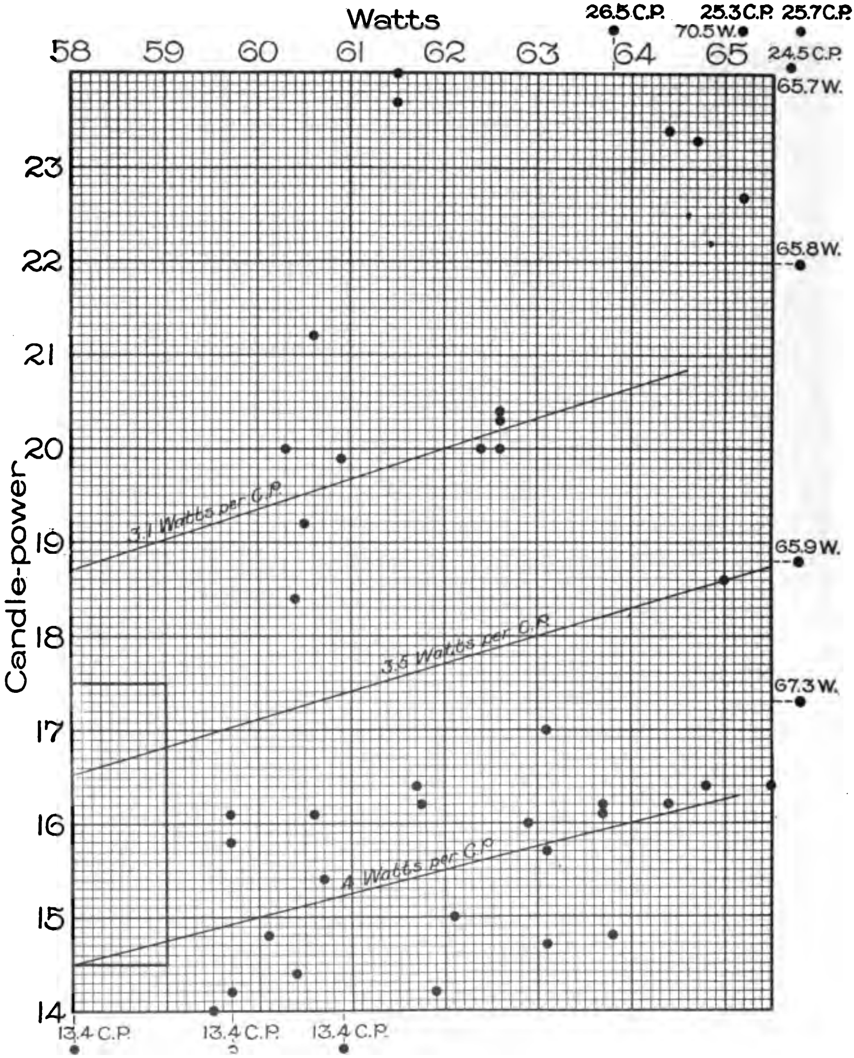
Showing Initial Candle-power and Watt Readings.



Lamp No. 9.—Illustrates lack of uniformity. Lamps measure from 12 C.P. to 20 C.P. and from 50 watts to 69 watts. Only 46 per cent. of lamps come within the limiting target.

TARGET DIAGRAM

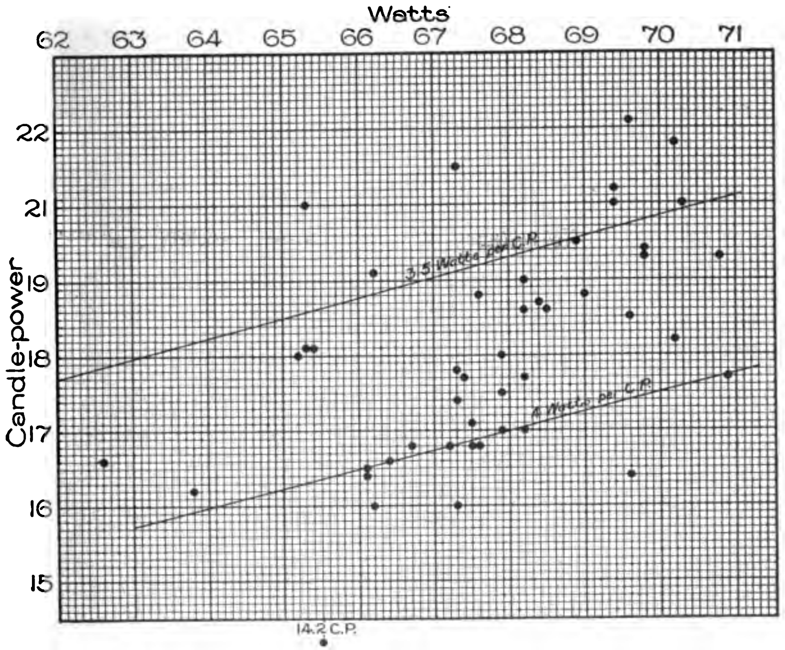
Showing Initial Candle-power and Watt Readings.



Lamp No. 1.—Illustrates extremely incorrect rating and great lack of uniformity. Lamps measure from 13.4 C.P. to 25.7 C.P. and from 58 to 67 watts. The watts per lamp average 62. None of the lamps come within the target, which had to be placed on one side with only a corner showing, in order to get the lamps on the diagram. Two lamps in the center at the top of the diagram take 61½ watts and give 23 to 24 C.P., burning, therefore, at an economy of 2.6 watts per candle Such lamps would give but short life at this high economy. This illustrates how lack of uniformity affects life.

TARGET DIAGRAM

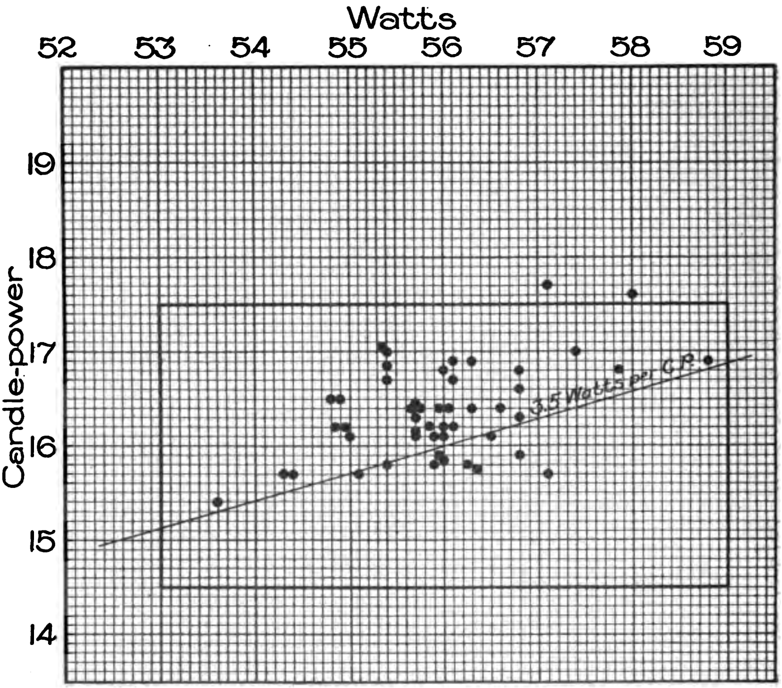
Showing Initial Candle-power and Watt Readings.



Lamp No. 11.—Illustrates extremely bad rating, especially in watts. Wattage is very high—so high that the target had to be omitted from diagram in order to include all the lamps—utterly outside of range called for. The candle-power runs from 16 to 21 candles and watts from 63 to 71 watts. The lamps average 18 to 19 candle-power and 67 watts—12 watts above rating called for.

TARGET DIAGRAM

Showing Initial Candle-power and Watt Readings.



Lamp No. 20.—Illustrates uniformity and correct rating. 96 per cent. of the lamps come within the limiting target. All lamps (except the two outside of the target) between 15½ and 17 candles and between 53½ and 59 watts. Note close bunching about center of diagram.

The above is what can be expected of well made and well selected lamps. One candle variation, 3½ to 4 watts variation. Perfectly proportionate and uniform product.

Maintenance of Candle-power.

The candle-power diagrams on the following pages illustrate the marked difference in maintenance of candle-power of various makes of lamps and show the characteristic results given by a high grade lamp. These diagrams, like the preceding ones, were plotted from the tests of a large commercial company on twelve leading makes of American lamps.

In a candle-power diagram, vertical distances from the bottom of the diagram represent candle-power, and horizontal distances from the left-hand side, the duration of time in hours.

Lamps were set up and burned, and readings are taken every 50 or 100 hours and plotted on a diagram, so as to form a series of points through which a curve was drawn for each lamp.

Special attention is directed to the value of plotting the individual curves of each lamp and from these forming an average curve, as was done in the tests here shown. This plan brings out an important point, viz.: the spread or variation in the candle-power performance which is not shown where the readings of each set of lamps under test are averaged and only one curve plotted.

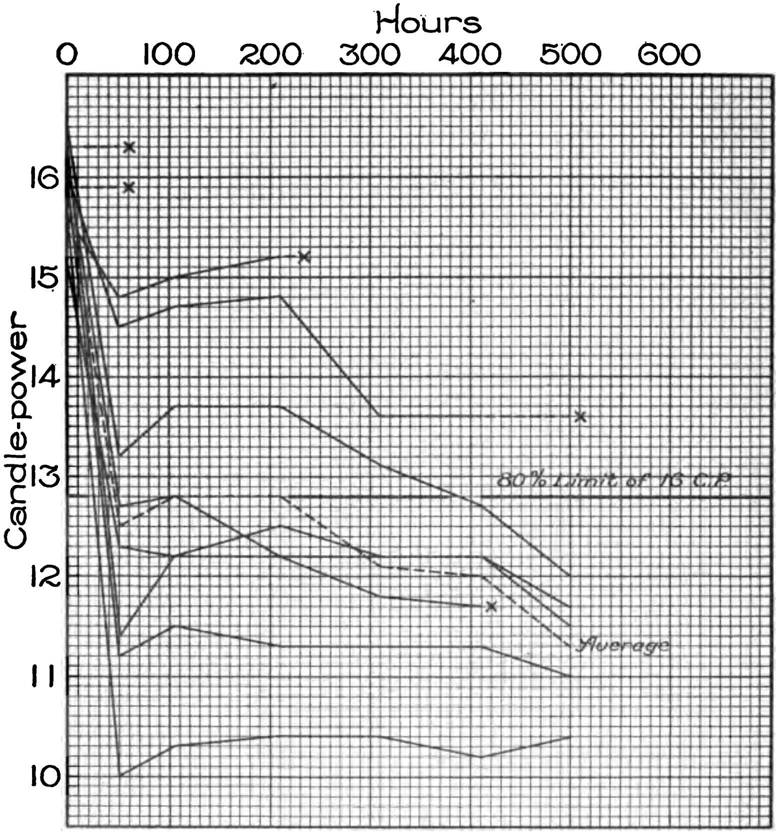
It will be noted that some of the lamps (Nos. 3, 9, and 12) decline 20% inside of the first fifty hours. Rapid drop in candle-power indicates extremely poor manufacture, and it should be remembered that many lamps now on the market will give like results.

A burning test of ten hours at normal or slightly excess voltage (normal voltage for 3.1 watt lamps, and 4 to 6 volts high for 3.5 and 4 watt lamps) will promptly reveal such lamps as numbers 3, 9 and 12, and thus enable customers to quickly determine poor quality.

Such a test gives results which a customer wants. but which are generally considered too much trouble to secure under the lengthy four to six hundred hour test, This method of test should be noted by all lamp purchasers.

CANDLE-POWER DIAGRAM

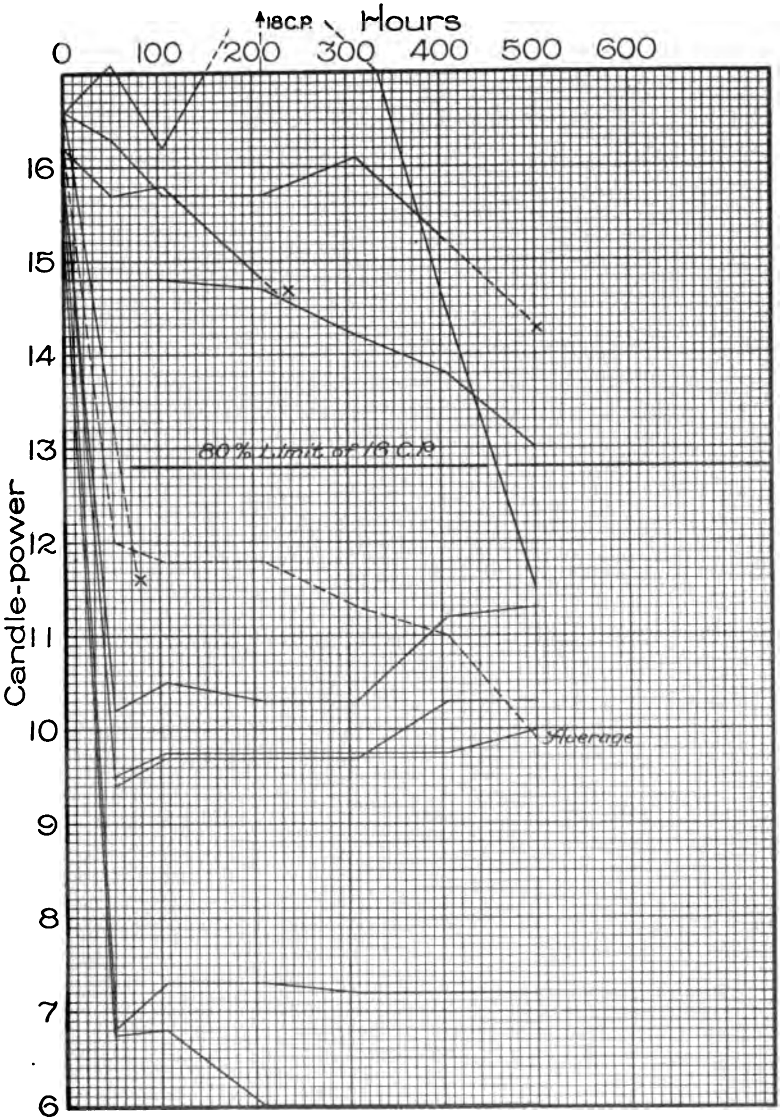
Showing Decline in Candle-power Under Service.



Lamp No. 12.—Illustrates rapid decline in candle-power of low grade lamps, a result due to extremely poor manufacture. Lamps are also not uniform after the first 50 hours. Breakage of lamps is bad, only five lamps completing the period of test—500 hours. The average curve reaches the 80 per cent. limit of 16 C.P. inside of the first 50 hours. Spread at 100 hours from 10½ candles to 15 candles.

CANDLE-POWER DIAGRAM

Showing Decline in Candle-power Under Service.

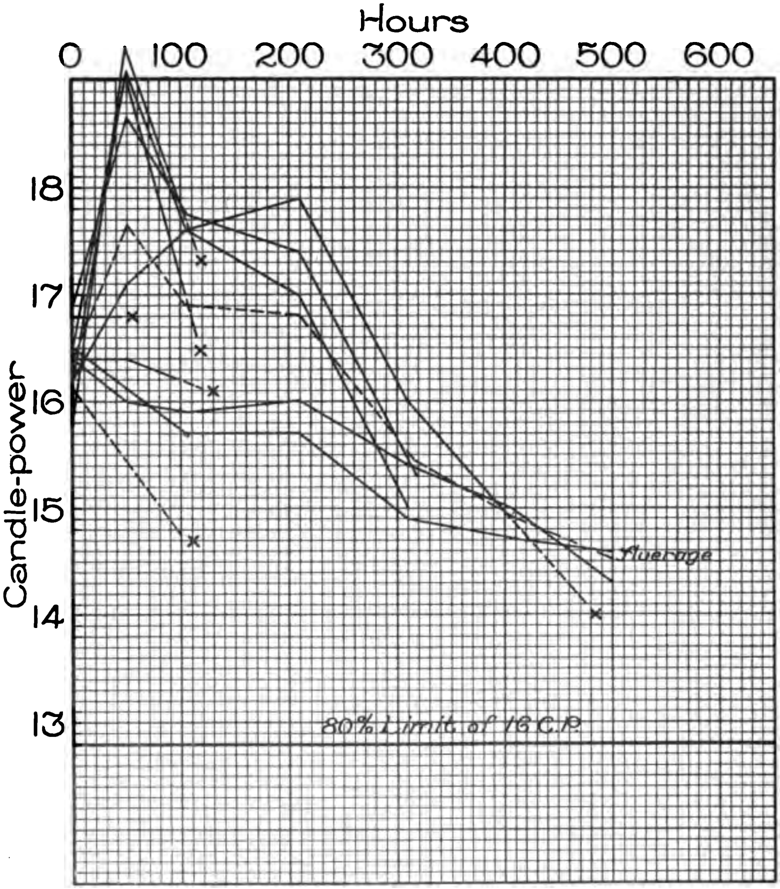


Lamp No. 9.—Illustrates rapid decline in candle-power of inferior grade lamps both individually and average; also wide range of results, no two lamps following the same path, but divergence so great that at 200 hours one lamp reads 18 C.P. and another 6 C.P. Such contrasts in lighting effects would surely cause dissatisfaction. Also note early breakage indicated by crosses where curves cease.

Above curves show the value of testing a number of lamps, and how many manufacturers deceive themselves and their customers. By testing only one or two lamps maximum results might be obtained, such as curves at top of this diagram, and thus a wrong value be established and wrong claims be made as to the quality of the lamp. Only by average results taken on a number of lamps giving all extremes can a true idea of a lamp's quality be formed. Average curve

CANDLE-POWER DIAGRAM

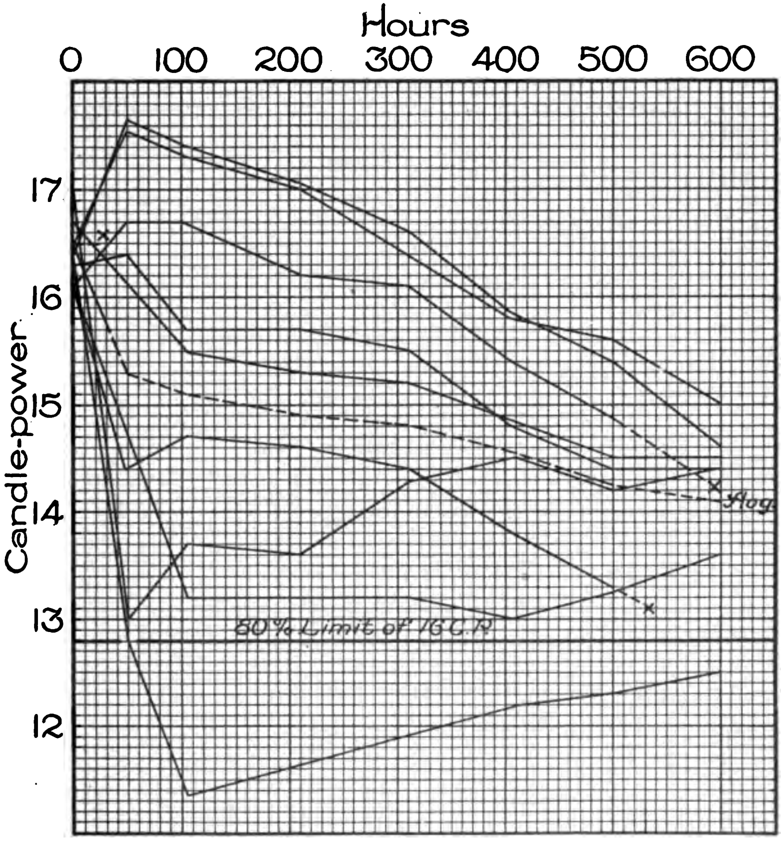
Showing Decline in Candle-power Under Service.



Lamp No. 13.—Illustrates extremely bad rise in candle-power at start and variation in performance. The early rise in candle-power by increasing the strain upon the filament causing it to burn at high economy, causes early breakage, as is shown by the number of lamps that fail within the first 125 hours. Only two lamps complete the period of test—500 hours. Incorrect rating of lamps caused them to average 16¼ candles at the start.

CANDLE-POWER DIAGRAM

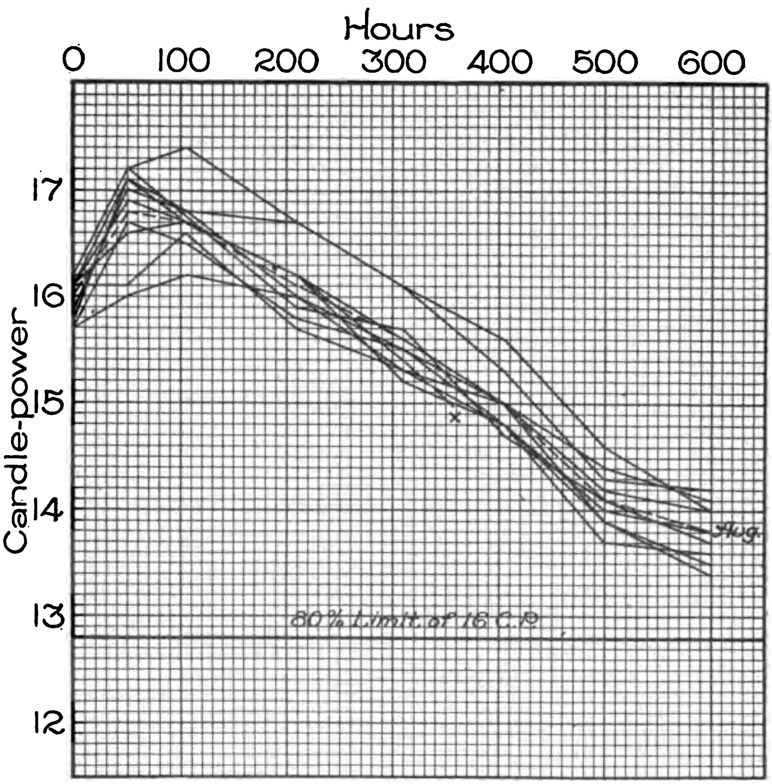
Showing Decline in Candle-power Under Service.



Lamp No. 3.—Illustrates extremely ununiform individual performance, although showing a fair average result. Emphasizes the importance of plotting individual curves of each lamp, instead of averaging results and plotting one curve. Candle-power spread at 100 hours 11½ to 17½ candles. Average curve at the rate of decline shown would probably reach 80 per cent. limit of 16 C.P. at 750 hours.

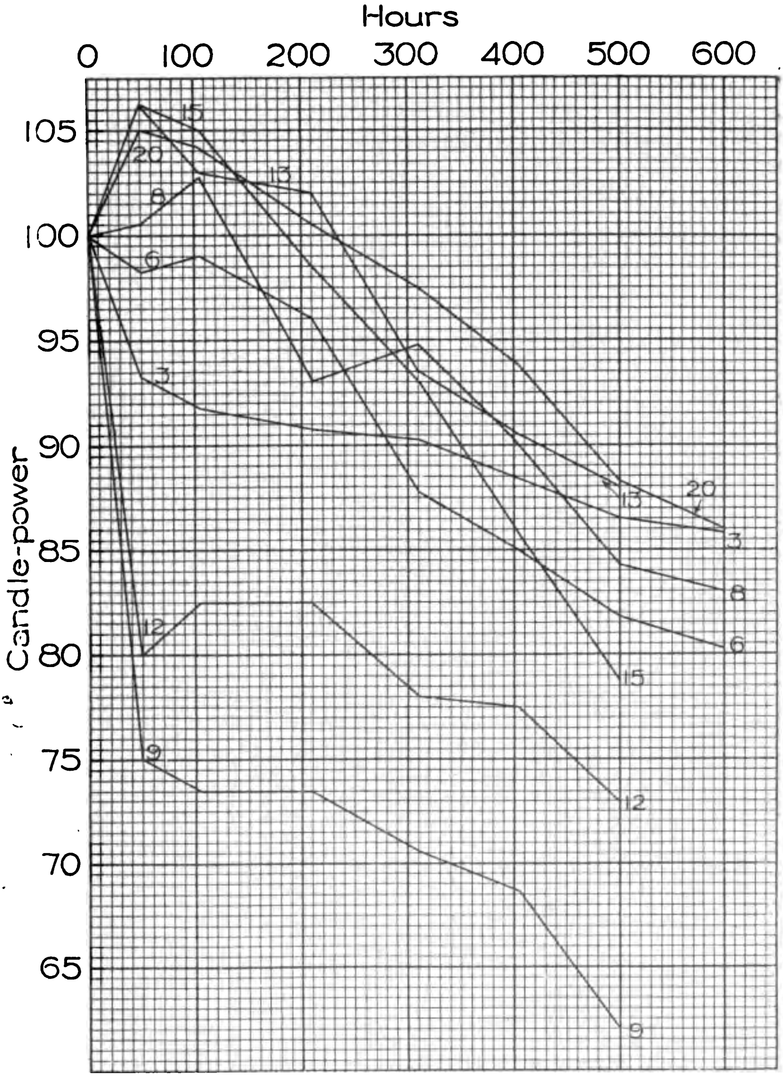
CANDLE-POWER DIAGRAM

Showing Decline in Candle-power Under Service.



Lamp No. 20.—Illustrates well maintained candle-power performance of high grade lamps. Also uniformity in individual and average results. All lamps follow practically the same path, having at no time a greater variation from highest to lowest than one candle. Note that only one lamp breaks during the entire period of test. The average curve does not decline to the 80% limit of 16 C.P. during the period of test—600 hours, and at the rate shown would not reach this limit before 850 hours.

CANDLE-POWER DIAGRAM.



Average Results.—The above diagram represents the average curves of eight leading makes of lamp and illustrates comparative results. It shows the marked differences existing between makes of lamps now on the market. Lamps Nos. 1 and 9 are apparently types of lamps that would be expensive to any central station as a gift.

RENEWAL OF DIM LAMPS.

The preceding curves clearly emphasize the importance of the second principle of good lighting service, namely, the frequent and regular renewal of old or dim lamps. All lamps lose in candle-power as they burn—some to a much greater degree than others. This depreciation of light must be repaired, and the only effective way is to replace the old lamps with new ones. A consideration of the loss of candle-power in lamps, as shown by the diagrams, should arouse the management of every prominent station to the necessity of adopting some system of lamp renewals which does not depend upon the customers and will limit the average life of the lamps to a period when they give from 12 to 16 candle-power. The limit of useful life on which the renewal systems of leading central stations are based is at present 80% of normal, that is 12.8 candle-power for a 16 candle-power lamp. The cleaning out of dim lamps cannot be left to the customer; it must be under the control of the central station.

TESTING OF LAMPS.

The preceding diagrams show the results of a test recently conducted by a large commercial company, to determine what lamp should be purchased for the annual supply of nearly 20,000 lamps. These tests included twelve leading makes of domestic lamps and were, perhaps, the most complete and impartial comparative tests of incandescent lamps ever conducted. They therefore serve as models for purchasers desiring to test incandescent lamps scientifically. The preliminary conditions necessary to complete an unbiased test are important. This fact was recognized in the tests just mentioned, and the following course was pursued

"First, the purchasing department bought in the open market, unknown to the manufacturers, twelve different makes of lamps. This included all leading makes and insured their obtaining average product, and avoided specially selected lamps. Second, they bought fifty lamps of each make, thus insuring sufficient lamps of each make to give fair average results. Third, they ordered the lamps all of one candle-power, efficiency and voltage—16 candle-power, 3.5 watts and 116 volts. This insured equality of conditions for the lamps. Fourth, they scratched off the labels and marked each lot of lamps by numbers, the individuals of each lot being numbered from one to fifty; then turned them over to the civil engineer of the company, the purchasing department withholding the names corresponding to the lot numbers. This insured against any personal bias on the part of the testing engineer, and further provided for tabulated results of each individual lamp. Fifth, all lamps were tested in a rotating-stand photometer. This insured very accurate readings in candle-power, and gave the mean horizontal candle-power of each lamp at every reading. Sixth, correct and reliable instruments were used."

The instruments used were as follows: A Weston direct current voltmeter, reading to $\frac{1}{10}$ volt, a Weston ammeter, reading to hundredths of an ampère, and a portable Bunsen photometer, with rotating stand attachment. See page 25.

The test was conducted as follows:

First, the lamps were all tested for initial candle-power and wattage at marked voltage. The readings on each lamp were noted opposite its number and these results afterwards plotted in the "Shotgun" diagrams, shown on pages 11 to 14.

This initial testing serves, like the physical test of the would-be soldier, to reject unfit applicants, and leave only the worthy lamps for the extended candle-power maintenance test. In this way, one make of lamp was found to be so bad as not to deserve even a complete preliminary test. Four makes were so poor that they were rejected at the end of the preliminary tests and the further candle-power performance tests were therefore limited to the seven remaining makes. (See pages 16 to 20).

After the initial candle-power tests, the seven remaining types of lamps were tested for candle-power

performance as follows: Ten lamps of each make were picked out of the seven remaining lots, those being selected that were nearest to the candle-power and efficiency ordered—that is, to 16 candle-power, 3.5 watts per candle at marked voltage. In this selection preference was given to the watts so that the different makes would burn as near as possible to the same efficiency, a necessary condition for correct comparative results.

The necessary number of sockets for life tests were so placed that the lamps burned in a horizontal position. Each socket was labeled to correspond with the lamps, so that after the test each lamp would go back into the same socket as before. In this way the filament would be kept in the same horizontal position throughout test, and the drooping tendency would be indicated. The voltage was kept constant and candle-power and ampere readings were taken on each lamp at the end of 50, 105, 210, 310, 405, 500 and 600 hours steady burning.

From the data thus obtained the candle-power curves of each lot of lamps were plotted on separate diagrams, each diagram showing the curves of the ten lamps. From each set of curves an average curve was deduced, and the average curves were plotted on one sheet for comparative results. (See page 21.) A comparison of the individual performances and the average curves clearly reveals the high grade lamps. The best lamp, according to the engineer's report, was worth four cents more than the next best, estimating lighting to cost 2½ cts. per Kw. hour, which is a low figure.

THE PHOTOMETER.

Although photometric work is extemely interesting, the crude photometers and standards formerly employed made it unreliable. Recognizing this difficulty, there has

THE PHOTOMETER.

been designed the simple and inexpensive form of photometer here illustrated. This photometer was immediately adopted by many central stations, and practical experience has shown that it is accurate, reliable, and easily operated.

THE SPOT BOX AND SCALE.

It can be purchased at the low price of $35.00 and the principal objection to lamp testing is thus removed, and photometry is made inexpensive, simple and interesting.

The instrument is of the standard Bunsen grease spot type, having a spot box which slides back and forth on two

brass rods. The scale is made of white celluloid fastened rigidly to the brass frame, and reads directly in candle-powers. An index pointer attached to the spot box slides over the scale. The binding posts provide for connection to a voltmeter, a wattmeter, or an ammeter and the line. A small German silver resistance coil and sliding contact furnish a suitable means for adjusting the voltage.

The accuracy of photometric work depends largely on the standards used. If they are variable and cannot be accurately set, accurate work is impossible. The special value in this type of photometer is in its constant yet

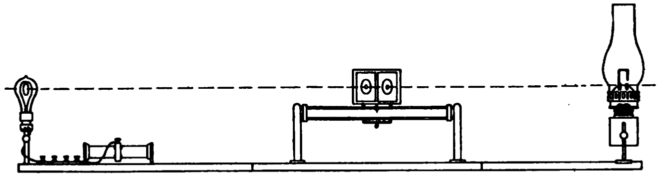
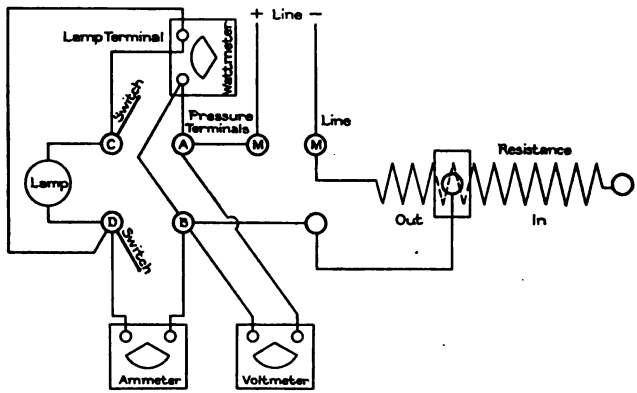


Diagram Showing Vertical Alignment of Incandescent Lamp and Oil Standard.

convenient working standard, a double burner kerosene oil lamp which is set to the correct intensity by comparison with a standard incandescent lamp placed at the opposite end of the photometer. Standard incandescent lamps are the most accurate and reliable primary standards obtainable. They are made for any approximate voltage, and when intended for standards, the voltage corresponding to a given candle-power may be marked to tenths of a volt. Standard lamps are used for only a few minutes at a time, and used in this way, seasoned low economy lamps undergo practically no change. The oil lamp, or working standard, is set by comparison with three standard photometer incandescent lamps provided with the outfit and held in the dummy socket, shown at the right. It should be noted that the primary standard always occupies the same position as the lamp to be tested. Therefore, tests

can be accurately made with this instrument even though the room be not entirely darkened.

The oil lamp is provided with adjustable screens that cut off the edges of the flame where flickering is apt to occur. The lamp is so adjusted that the flames burn low, thus ensuring an even light that will remain constant for hours without adjustment. Two curtains are arranged,



Voltmeter—To binding posts A and B.
Ammeter—To binding posts D and B (switch open).
Wattmeter—Pressure terminals to binding posts A and B. Lamp terminals to binding posts C and D. Both switches open.
Line—To binding posts M and M.

DIAGRAM OF CONNECTIONS OF PHOTOMETER.

as shown, to protect the eyes of the operator from the light.

The oil standard was adopted after extensive experiments to prove its thorough reliability. It is extremely convenient and satisfactory, as it gives a constant light independent of the fluctuations of the voltage.

The portable photometer telescopes compactly into a space 24″ x 6″ x 9″. It is furnished with a canvas carrying case, and the whole outfit weighs only 12 pounds. Each photometer is accompanied with instructions and a

diagram of connections. Only two instruments, which should be in the possession of every central station, are necessary with the photometer, namely, a voltmeter and an ammeter or wattmeter.

The preceding account of an important commercial lamp test clearly illustrates the correct method of procedure. The following additional suggestions, however, may be of value.

Initial tests for accuracy in candle-power and wattage should be made on as many lamps of each make as possible—never less than fifty unless this number of lamps is not available. Each lamp should be numbered, and its readings in candle-power and watts recorded in a table similar to the following.

Make of Lamp.	Number.	Voltage.	Candle-power.	Watts.

When readings have been made and noted as above described, they should be plotted for each make of lamp on a target diagram. These diagrams portray irregularity in a more striking manner than can be shown by a column of figures. Diagrams for this purpose can be obtained from the General Electric Company, Harrison, N. J.

The voltage should be kept constant by means of the slider while the lamp is being tested, and each lamp should be tested at its marked voltage.

The following instruments should be used:

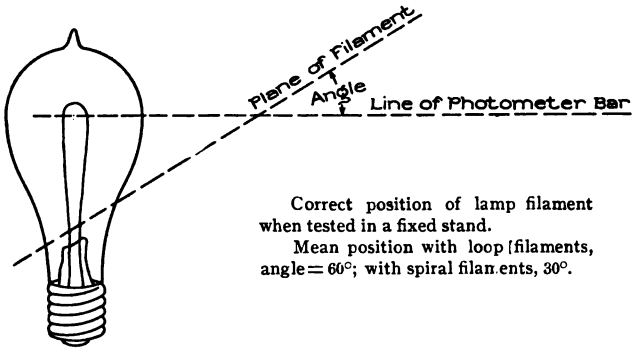
Direct Current Voltmeter, readable to $\frac{1}{10}$ volt,

Direct Current Ammeter, (mil-ampere type) readable to $\frac{1}{1000}$ ampere.

Ammeters require a finely divided scale and careful readings for correct results, but they are preferable to wattmeters. Direct current should be used wherever

possible because of the greater accuracy of direct current instruments.

The leading lamp manufacturers now use a revolving stand in making photometric measurements. In a photometer of this type, the lamp is arranged to revolve in a vertical position at about 180 revolutions per minute. The photometer described on page 25 can be obtained with either a fixed or revolving stand. When using a



Correct position of lamp filament when tested in a fixed stand.

Mean position with loop filaments, angle = 60°; with spiral filaments, 30°.

fixed stand, the lamps must be adjusted to the mean position, which is different with different types of filaments. With the loop or horseshoe filament, the lamp should be adjusted so that the angle between the plane of the filament and the line through the spot box and lamps is 60°. For the spiral and oval forms of filaments, this angle should be 30°. Care should be taken to set each lamp at its proper fixed position before making readings.

Comparative tests should be made on lamps of the same voltage and candle-power. A 50 volt lamp should give a better candle-power curve than a 100 volt lamp of the same make. Similarly, a 32 candle-power lamp

should give better results than a 16 candle-power lamp, and a 16 candle-power lamp better than a 10 candle-power lamp. Therefore, it would not be fair to compare the actual results given by a 50 volt lamp of one make with those given by a 100 volt lamp of another make, or of lamps of different candle-powers.

Candle-power readings on each lamp taken at the various periods should be noted in a table like the following.

CANDLE-POWER READINGS.

Make of Lamp.	Number of Lamp.	HOURS.				
		0	30	50	100	etc.

From these tables, the results on each lamp should then be plotted in a curve. Blanks for this purpose can be obtained from the General Electric Company, Harrison, N. J.

Readings need not be taken after a lamp loses 20% in candle-power; that is, after a 16 candle-power lamp drops to 12.8 candle-power.

A test of 30 to 50 hours is frequently sufficient on low grade lamps, and will bring out results similar to those shown on pages 16 and 17, thus rendering further tests unnecessary.

Do not waste time by making candle-power performance tests on lamps that show a great lack of uniformity or wide variation from correct rating in either candle-power or watts on initial tests. (See pages 12 and 13.) Such lamps stand condemned already.

Remember that it is of the utmost importance to consider only average results on a number of lamps and not depend on individual results.

For candle-power performance tests, at least ten to twenty lamps of each make should be set up. A number of sockets should be placed so as to burn lamps in a horizontal position, thus bringing out any drooping effect, and each lamp should have the same socket throughout the entire test. The sockets should be placed at least eight inches apart so as to reduce the effect of heating, and each make of lamp should be placed in vertical rows or an equal number of each make in each horizontal row. This arrangement subjects each make to the same heating effect and is thus an essential condition to a correct comparative test. (See testing board shown on page 34).

The voltage should be kept as nearly constant as possible and should agree with the rated voltage of the lamp. In any event, all lamps under test should be subjected to the same conditions of voltage regulation.

For correct comparative results, the initial economy in watts per candle should average exactly the same for each make of lamp under test. A difference of one-tenth watt is a great disadvantage to the lamp of higher economy. For example, a lamp using 3.2 watts per candle at the beginning of the test has a marked advantage over another lamp using 3.1 watts per candle. In case it is not possible to secure lamps having the same initial watts per candle, then the proper correction factor must be applied afterward.

Such a correction factor is, however, difficult to determine. The best and most satisfactory way is to secure, at the start, exact equality of initial economy in watts per candle. If the lamps are not of equal initial economy, make them so by increasing or decreasing the voltage and consequently the candle-power. The proper amount of increase or decrease of voltage can be readily determined by a few trial readings.*

* Should there be a great variation from the specified economy among lamps of any make, the lamps should be rejected at the initial test and should not be given a candle-power performance test.

For example, suppose we are to start a candle-power performance test at an economy of 3.1 watts per candle, and we have a lamp marked 16 c.p., 116 volts, which takes, when tested at 116 volts, 3.29 watts per candle. By raising the voltage to 119 we increase the candle-power to 17.5 and secure the economy desired, *i. e.*, 3.1 watts per candle. Therefore, by burning this lamp at 119 volts it will be brought to the same temperature and strain at which the other lamps are burned. Note that in the performance test the limiting candle-power for this lamp would then be 80% of 17½ candle-power.

The only objection to this method is that it requires different voltages for the different lamps burning on the test rack. This, however, is easily arranged by having the voltage sufficiently high and then reducing it wherever necessary by a small German silver resistance in series with the lamp.

RELATIVE VALUES OF LAMPS.

How They May Be Determined.

To determine the relative values of various lamps a correct basis of comparison must be established. Comparison should not be made solely on the life of the lamp, since the candle-power may diminish rapidly as in lamps No. 9, page 17.

The proper basis of comparison considers both life and candle-power, and is the average life of the lamps measured to a certain limit of candle-power. This period is called the *useful* life of the lamp, and the best lamp is that which under certain conditions (noted on the preceding pages) gives the longest period of *useful* life.

Many central stations today consider that a lamp has passed its useful life when it has lost 20% in candle-

power, *i. e.*, when it has declined to 80% of its initial candle-power.

Using the 80% limit for comparison we can at once determine the relative values of lamps.

For example, the average curve of lamp No. 9, page 17, crosses the 80% limit line at 40 hours, while the average curve of lamp No. 20, (page 20) would, when prolonged, reach the same limit at about 800 hours.

Lamp No. 9, would, therefore, require renewing twenty times as often as lamp No. 20, and the value of lamp No. 20 would consequently be twenty times as much as the value of lamp No. 9. In reality the cost of attendance for the much more frequent renewals of lamp No. 9 would still further reduce its relative value.

It should be borne in mind that for this method of comparison uniform conditions are essential.

THE LIMIT OF USEFUL LIFE OF A LAMP.

As all lamps decline in candle-power during service, their limit of usefulness is sooner or later reached. The limit taken will depend upon various conditions, and may not only vary with different companies, but with the different classes of customers supplied by one company. The point to be noted is that there should be some fixed limit at which the old lamps should be replaced by new ones. Lamps should not be allowed to burn through a dim and useless old age until burned out.

Lamp testing should determine two things:

First: Which is the best lamp, and

Second: What is the useful life of the lamps in service; or, in other words, what to use and how to use it.

Acting on the knowledge thus obtained, central station managers should aim to renew lamps so as to keep the average life within the period of useful life determined. This is the best practice and secures the highest quality of lighting service.

INCANDESCENT LAMP TESTING BOARD.